

**ADDITIONAL HEARING SCREENINGS IN PEDIATRICS:
DOES EARLIER, MORE CONSISTENT SCREENING MAKE A DIFFERENCE?**

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Abstract:

Congenital and acquired hearing losses in infants and/or children have been shown to lead to poor academic performance, speech and language delays and disabilities, and emotional and social difficulties. Additionally, some cases of congenital hearing loss may not be able to be detected in a newborn hearing screening and therefore may not be detected until a child is showing some degree of hearing loss or has even reached school-age, where annual hearing screenings are then performed. Evidence has shown that newborn hearing screenings have improved the detection, diagnosis, and outcome for children with hearing loss. However, from birth to five years of age, there are several different recommendations for hearing screenings from reputable sources, which lead to practice variation between clinics, hospitals, and cities. Phoenix Children's Hospital has implemented a program, following the guidelines set by the Ear Foundation, to do annual hearing screenings from birth to school age (approximately five years old). This is in contrast to the recommendations set by Bright Futures, which state that hearing screenings should be done at birth and then annually after the child has begun kindergarten. Therefore, this project aims to determine if additional hearing screenings in pediatric patients from one to five years of age result in earlier detection of potential hearing impairments and in interventions prompted by this earlier detection. This particular study is a retrospective chart review of pediatric patients at Phoenix Children's Hospital's ambulatory clinic who received annual hearing screenings at their well-child checks from birth to five years of age in comparison to children who had been screened at birth and then not again until school-aged. The patients reviewed were between six months to five years of age with 1,721 patients screened based on the Bright Futures recommendation and 1,200 patients screened based on the Ear Foundation recommendations. Of the 1,200 patients screened based on the Ear Foundation recommendations, there were 103 failed screenings that were referred to either Audiology or ENT. Of those 103, there were 39 children who were identified with some pathology, with 16 children receiving an intervention. The most common intervention was bilateral tympanostomy tube placement (eight children), along with four other children also needing an adenoidectomy and/or tonsillectomy or myringotomy. Two children had extruded

tympanostomy tubes removed, one child was noted to receive antibiotics for acute otitis media (AOM), and one child was diagnosed with sensorineural hearing loss and given hearing aids.

The results of this study help to determine the incidence of failed hearing screenings and required interventions comparing two different screening protocols (Ear Foundation and Bright Futures). This data also helps to determine the frequency with which failed hearing screenings translated to an intervention that improved the clinical outcome for the patient. The impact of these findings may then prove to drive clinical decisions on the frequency and total number of hearing screenings performed at routine preventative care visits in general pediatric practice(s).

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Introduction/Significance:

It has been shown, and almost universally accepted, that newborn hearing screenings have improved the detection, diagnosis, and outcome for children with hearing loss. However, there is an incomplete screening protocol for children during their early developmental years, mainly between birth and five years of age. The American Academy of Pediatrics uses the recommendations for hearing screenings based on Bright Futures. Bright Futures recommends newborn hearing screenings and then annual hearing screenings after the child has started kindergarten or reached “school age” (around five years of age)¹. Additional hearing screenings between this time are only warranted, by this recommendation, from a failed newborn hearing screening, parental concern, or developmental delays (speech delay, etc.). This is contrast to the recommendations set forth by the Ear Foundation, an organization prominent here in Arizona. Under these recommendations, children are screened annually (after birth) at their well-child checks regardless of the outcome(s) of the newborn screening test, or any prior screening².

This study aims to determine if additional, more regular screening tests are warranted, and if the benefits outweigh the costs of screening and/or potential follow-ups (whether true or false positives). A study published in the Journal of Developmental Behavioral Pediatrics, by P. Bhatia, implemented an infant-toddler hearing screening program during well-child visits between birth and five years of age. They were able to perform an additional 1,965 otoacoustic emissions (OAE) hearing tests in patients from birth to five years of age. 75% of the screenings took less than ten minutes of their well-child check. 45 cases (22%) raised concerns for sensorineural hearing loss, and five of these patients had confirmed permanent sensorineural hearing loss³. An article by J. Lu article used a retrospective review of preschool-aged children (between birth and five years of age) to help identify hearing impairments earlier on than in a sporadic group of pediatric patients. 34,321 preschool children underwent screening for delayed-onset hearing loss, and sporadic cases of delayed-onset hearing loss were selected from pediatric patient records. The two groups were given a questionnaire to record risk

factors, any diagnoses, and age at any interventions. The average age of children at the time of diagnosis in the screening group was significantly earlier than in the cases identified in the sporadic group, and the age of intervention of children with bilateral hearing loss in the screening group was also earlier than in the sporadic group. Through this, they were able to conclude that early diagnosis can be achieved with hearing screening for preschool children with no previous symptoms of delayed-onset hearing loss (for example, from a failed newborn screening test, parental concern, etc.)⁴.

Another, additional article by J. Lu examined the prevalence of delayed-onset hearing loss in preschool children who, more specifically, had previously passed their newborn hearing tests. They used pediatric audiometers to identify delayed-onset hearing loss, and those with positive results were sent for follow-up and assessed for other risk factors. They found that 445 children were referred for audiologic assessment after these additional screenings and that 16 of these patients had permanent delayed-onset hearing loss. The importance of the delayed onset, in this study specifically, was due to established risk factors that included parental concern regarding speech and language delays, being in the neonatal intensive care unit with assisted ventilation, hyperbilirubinemia, recurrent otitis media with effusion, craniofacial malformation, and family history⁵. Finally, an article by T. Okano focused on periodical health checkups to identify infants with hearing impairment(s) earlier in life. Twenty-four cases of patients between birth and one year of age were diagnosed as having the need for hearing aids and were assigned to treatment and further education. This resulted in higher efficacy of interventions, even in severe cases of patients with unilateral or bilateral conductive or sensorineural hearing loss⁶.

One of the first and most significant signs of hearing loss is a speech or language delay. This may not be recognized until a child is two or three years of age, well during or even after some of the most critical periods for speech and language development. This is something that could potentially be ameliorated with more frequent hearing screenings and earlier interventions for patients who fail these more frequent hearing screenings.

RESEARCH QUESTION: Do additional hearing screenings in pediatric patients from one to five years of age result in early detection of potential hearing impairments, and if so, what are possible, successful interventions? This study will be a retrospective chart review of pediatric patients in this population at Phoenix Children's Hospital who received annual hearing screening from birth to five years of age in comparison to children who had been screened at birth and then not again until school-aged (five years of age or so). Children who did receive annual hearing screenings, and failed screening at any point, will be reviewed further for follow-up information and possible intervention(s).

Hypothesis: We hypothesize that, per the recommendations set forth by the Ear Foundation, children between the ages of one and five who receive early, consistent hearing screening are consistently diagnosed with hearing impairments if they are present before young children of comparable ages who are screened irregularly throughout that same time period. We also hypothesize that, those patients who fail any part of these hearing screenings, participate in effective follow-up testing and potential, earlier intervention(s).

While many failed hearing screenings do not result in these severe cases or diagnoses, the simplicity of the hearing screening test(s) and impact it has the potential to make on pediatric patients with permanent hearing loss, in many researchers' opinions, warrants the additional hearing screenings during the most critical years in postnatal development. There seems to be a significant gap in the literature relating to annual hearing screenings between birth and five years of age. This, along with the several different recommendations from reputable sources, leads to a disconnect between clinics, hospitals, cities, states, and even countries. Phoenix Children's Hospital has implemented a program, following the guidelines set by the Ear Foundation, where they do annual hearing screenings from birth to school age. This is in contrast to the recommendations set by Bright Futures, which state that hearing screenings should be done at birth and then annually after the child has begun kindergarten. Despite these recommendations, there is a rising, more general trend that shows that additional hearing screenings lead to successful and earlier intervention(s). This study,

therefore, relates to hearing screenings in pediatric patients from birth to school age (around five years of age) to see if these additional hearing screenings are successful in detecting potential hearing impairments and warranted in clinical practice.

Methods and Materials:

Subjects:

Pediatric patients from the Phoenix Children's Hospital outpatient/ambulatory clinic were included in this study when in the clinic for their well-child check. These patients were between six months to five years of age, and this screening was viewed and explained as another service from the clinic. These additional screenings were based from a grant given to the clinic to allow for additional hearing screening tests to determine if these additional and earlier hearing screenings result in any effective follow-up and/or successful interventions. This study was done via a retrospective chart review from pediatric patients from the outpatient clinic. There were approximately 1,721 patients screened based on the Bright Futures recommendation, the group that did not receive the additional screenings or intervention. These patients were screened at birth and then annually after school-age (approximately five years of age) unless they failed their newborn screen or had any additional concerns (speech delay, etc.) between that time period. There were 1,200 patients screened based on the Ear Foundation recommendations/intervention, given additional screenings between birth and five years of age at every annual well-child check, regardless of the outcome of the newborn hearing screen or presence or lack of additional concerns or developmental delays. This study aims to compare the number of hearing screenings before implementing the new recommendations, and after this implementation, and additionally, quantify failed hearing screenings and their outcomes.

Hearing Screenings:

The type of hearing screenings performed depended on the age of the child. Most screenings were performed via an otoacoustic emissions hearing test (OAE). These sounds test the function of the inner ear (cochlea) as well as the auditory nerve. Small probes are placed in the ear. One delivers a series of beeping and impeding sounds, while the other is a microphone that, in a functioning cochlea, will reverberate and echo the sounds back from the ear drum and in to the machine. Any blockage, even fluid in the ears, will prevent the sounds from making their way to the machine to be able to be read. For older children, a pure-tone hearing test may have been performed. Pure-tone audiometry presents tones across the speech

spectrum (500 to 4,000 Hz). The testing involves the patients raising their hands when hearing sounds or beeps at different frequencies and decibels of sound. This test can determine the degree, type, and configuration of hearing loss.

Referrals to Specialty/Outcomes:

It is important to note that, while these procedures (OAE and pure-tone hearing tests) do test the conduction of sound through the ear and cochlea, they cannot definitively diagnose deafness or hearing loss. If the patient failed screening with either of these tests, they were referred for additional testing and follow-up with a specialist. Referrals were made to Audiology and/or otolaryngology (ENT). This study also examined how many of these screening tests were failed and what implications that resulted in. For example, failed screening tests can be caused by a number of factors: Eustachian tube dysfunction, middle ear effusion, sensorineural hearing loss, and conductive hearing loss. Because of this, the number of referrals to specialty, and their outcomes, were also examined to determine the efficiency and effectiveness of additional screening.

Results:

Table 1 depicts the likelihood of an abnormal outcome following a failed hearing screen and subsequent referral visit to Audiology or ENT. Of the 1,200 children screened per the Ear Foundation recommendations receiving annual hearing screenings at well-child checks, there were 103 failed screenings. Of these 103 children, the average age of the failed screening was 2.85. 64 of those children had a normal outcome at the referral visit, with 39 children with an abnormal outcome. 62 of the children with an initial failed hearing screen were male, with 28 of them with confirmed abnormal hearing. This resulted in a p-value of 0.043. Statistics were calculated using a multiple logistic regression to formulate an odds ratio with a 95% confidence interval.

Table 2 portrays the likelihood of an intervention following an abnormal outcome at the patient's referral visit (either Audiology or ENT). Of the 39 children who had an abnormal outcome from their referral, 16 received some sort of intervention. The average age of children needing an intervention was 2.67, with the intervention occurring at an average age of 2.95. These two values were statistically significant, with p-values of 0.04 and 0.044, respectively. There was no significant difference between males and females in needing an intervention, but there was a statistically significant difference in Hispanics receiving an intervention over other ethnicities (p- value of 0.035).

Table 3 discusses the various interventions that the 16 children received. Half of the children (eight) had bilateral tympanostomy tubes placed, with four others receiving tympanostomy tubes as well as either an adenoidectomy, tonsillectomy, adenotonsillectomy, or myringotomy. Two children had extruded tubes removed, and one child was given antibiotics for the treatment of acute otitis media (AOM). Finally, one child was diagnosed with sensorineural hearing loss and given hearing aids.

Table 1: Likelihood of Abnormal Outcome Following Referral Visit

Variables.	Overall N=103	Normal Outcome (N=64)	Abnormal Outcome (N=39)	Odds Ratio (95% CI)	P-value ¹
Age at Screening, Years (mean, SD)	2.85 (1.47)	2.91 (1.38)	2.75 (1.62)	0.16 (0.009, 2.60)	0.19
Age at Completion, Years (mean, SD)	1.99 (1.49)	3.04 (1.37)	2.90 (1.71)	5.51 (0.34, 87.0)	0.23
Gender (male, %)	62 (60.2)	34 (53.1)	28 (71.8)	2.68 (1.02, 7.00)	0.043
Ethnicity (N, %)					
Caucasian	36 (34.9)	23 (35.9)	13 (33.3)	REF	
African American	13 (12.6)	9 (14.1)	4 (10.3)	1.04 (0.23, 4.77)	0.95
Hispanic	42 (40.8)	27 (42.2)	15 (38.5)	1.21 (0.42, 3.48)	0.72
Other	12 (11.7)	5 (7.81)	7 (17.9)	4.42 (1.01, 19.3)	0.048
Language (English, %)	83 (80.6)	53 (82.8)	30 (76.9)	0.52 (0.17, 1.58)	0.25

¹Odds Ratio (95% CI) calculated using Multiple Logistic Regression adjusting for all other variables.

Table 2: Likelihood of Intervention Following Referral Visit Among Those with Abnormal Outcomes

Variables	Overall N=39	No Intervention (N=23)	Yes Intervention (N=16)	Odds Ratio (95% CI)	P-value ¹
Age at Screening, Years (mean, SD)	2.75 (1.62)	2.82 (1.59)	2.67 (1.71)	0.002 (6.23e-.06, 0.75)	0.04
Age at Completion, Years (mean, SD)	2.90 (1.71)	2.86 (1.57)	2.95 (1.95)	326.9 (1.16, 9.1e4)	0.044
Gender (male, %)	28 (71.8)	18 (78.3)	10 (62.5)	0.42 (0.06, 2.76)	0.37
Ethnicity (N, %)					
Caucasian	13 (33.3)	6 (26.1)	7 (43.8)	REF	
African American	4 (10.3)	2 (8.70)	2 (12.5)	0.20 (0.007, 5.83)	0.35
Hispanic	15 (38.5)	12 (52.2)	3 (18.8)	0.10 (0.01, 8.95)	0.035
Other	7 (17.9)	3 (13.0)	4 (25.0)	1.11 (0.13, 8.95)	0.91
Language (English, %)	2.75 (1.62)	17 (73.9)	13 (81.3)	0.92	0.92

¹Odds Ratio (95% CI) calculated using Multiple Logistic Regression adjusting for all other variables.

Table 3: Types of interventions

Interventions	(N, %) N=16
Antibiotics for AOM	1 (6.25)
Bilateral myringotomy with tympanostomy tube insertion	1 (6.25)
Extruded tubes removed	2 (12.5)
Hearing aids placed	1 (6.25)
Nasal steroid spray, adenotonsillectomy (after age three)	1 (6.25)
Tympanostomy and adenoidectomy	1 (6.25)
Tympanostomy tubes placed bilaterally	8 (50.0)
Tympanostomy tubes, tonsillectomy, adenoidectomy	1 (6.25)

Discussion:

The results of this study may help determine the incidence of failed hearing screenings based on the Ear Foundation recommendations, which are more frequent than current Bright Futures recommendations. This data also correlates with the frequency with which failed hearing screening translated to an intervention for the patient. While it is unclear whether the majority of these interventions (tympanostomy tube placement, etc.) would have not occurred until the age of five, or after Bright Futures recommends beginning annual hearing screening, it is still important to recognize the timing and majority of the patients with a failed screening and subsequent intervention. Most of the patients that were identified as having a failed hearing screening were either two or three years of age, which is earlier than current Bright Futures recommendation for screening. These patients potentially would not have been screened until up to three years later. The children that then continued to have an abnormality and require an intervention were also mostly between two and three years of age as well. The categories that proved to be statistically significant ($p\text{-value} < 0.05$) were gender (males), ethnicity (Hispanic), age at screening at referral appointment (mean 2.75 years), and age of completion of intervention (mean 2.90 years). These characteristics prove to be important in deciding if annual hearing screenings are beneficial, and to what capacity. For example, according to this data, the most high-risk group for abnormal hearing screenings, referrals, and need for intervention were Hispanic males between the ages of two and three. Therefore, further studies may help to determine if it is warranted to target these specific demographics with earlier and more frequent hearing screening.

This study had several strengths, including a large initial sample size, ease of performing the screening, and ability to follow up on patients with a failed screening test. This was in part to the hospital's electronic medical record and ability to view referrals and outcomes through this. One of the weaknesses of the study was that it was not specified whether the hearing screening performed was via otoacoustic emissions (OAE) or through a pure-tone hearing test. Pure-tone hearing tests are usually administered to older children (school-age). Because this screening now incorporated children who were slightly younger than "school-age", they may

have used this screening tool instead of the more traditional OAE. The pure-tone hearing test involves children raising their hand when they hear a beep at different levels of frequency. Child cooperation, therefore, could have been a factor for these older children. The study also only looked at the failed screenings via the Ear Foundation recommendations and did not directly compare detection of hearing loss with the two different recommendations for screening. This study also did not investigate whether the children who failed early screening had any concerning symptoms such as speech delay, not turning their head in the direction of sound, and/or difficulties in preschool, which may have prompted earlier testing. Because Bright Futures recommends screening children at age five (school-aged), these patients were out of range for the study and would've been screened and followed up anyways if a failed hearing screen was detected. Additionally, of the 1,200 children screened via the Ear Foundation recommendations, only 103 had failed hearing screenings. This correlates to only 8.5% of patients failing their annual hearing screen. However, of the 39 children that failed their hearing screen at their subsequent referral, 16 of those children qualified for an intervention, correlating to 41% of these patients receiving some sort of intervention.

Every year, there are between 4,000 and 8,000 children born here in the United States with permanent hearing loss with their hearing loss posing a major risk for significant speech and language delays⁷. There are almost double the amount of children with milder hearing losses or losses only affecting one ear⁷. Congenital or acquired hearing losses in infants and/or children have been shown to lead to poor academic performance, speech and language delays and disabilities, and emotional and social difficulties. Additionally, some of these congenital hearing losses may not be able to be detected in a newborn hearing screening and therefore may not be detected until a child is showing some degree of hearing loss or has even reached school-age, where hearing screenings are then, by recommendations by Bright Futures, done annually. Infectious diseases (such as recurrent otitis media) and/or trauma can also lead to potentially reversible hearing loss if identified and treated in an appropriate amount of time.

Future Directions:

In an article from the Journal of the American Medical Association (JAMA), D. Halloran discusses the Joint Committee on Infant Hearing, which, as of 2005, not only advocates universal newborn hearing screening, but also periodic screening throughout childhood⁸. At that time, recommendations from the American Academy of Pediatrics (AAP) advocated hearing screening at four, five, and six years of age, as well as at eight, ten, twelve, fifteen, and eighteen years of age, regardless of the presence or absence of risk factors for hearing loss. Prior to 2000, the recommendation was to begin screening at three years of age, but the current standard is still now to start screening at four years old⁹. If a child fails the screening and has a normal appearing tympanic membrane (TM), the recommendations are to refer them to either ENT or Audiology.

Most studies in the past have only addressed failed newborn screenings or have mainly included school-aged children. Our study, as well as several of the studies from J. Lu and others previously mentioned, have targeted younger children, mainly those that are preschool-aged. Additional studies to assess periodic hearing screening in primary care settings for children in this age group could help solidify these recommendations and advocate for earlier, more consistent screening. A more thorough investigation on risk factors could also more specifically target patients who may benefit from more consistent screening. For example, our study has statistical significance in the fact that males between the ages of two and three have a higher likelihood of a failed hearing screening and subsequent referral and intervention. Could these demographics and other patient risk factors help guide the formation of new recommendations for hearing screening at annual well-child checks? The impact of these findings may prove to drive clinical decisions on the frequency and total number of hearing screenings performed at routine visits in general pediatric practices, specifically at Phoenix Children's Hospital.

Conclusions:

Earlier identification of hearing impairments through annual hearing screenings can lead to more successful outcomes and reduce and maybe even prevent these developmental issues and delays from occurring. In the past, late diagnosis of congenital hearing loss occurred with diagnosis and intervention up to three years after initial signs or parental concern⁷. Now, with improved technology and access to screening tools and interventions, diagnosis can occur earlier with more successful treatments. Additionally, this data and its outcomes may prove to act as a novel approach to the timing and importance of annual hearing screening in pediatric practice. On a more global scale, recommendations may be updated by other organizations and set the timing of these additional hearing screenings in other practices in other areas. It may also prove to be a driver to insurance companies/plans for coverage of basic screening services. However, the lower number of failed screening tests, and even lower number of actual diagnoses through Audiology or ENT, may prove that there is less utility in screening every patient at an annual well-child check. Past and future studies will, hopefully, help to determine the most effective number of hearing screenings that should be performed prior to kindergarten, and at what time.

Per the recommendations set forth by the Ear Foundation, we expected that children who received early, annual hearing screening would be diagnosed with hearing impairments if they are present before young children of comparable ages who are screened irregularly throughout that same time period (Bright Futures). Patients who failed any part of these hearing screenings were able to participate in appropriate follow-up with successful intervention. These additional screenings accounted for 39 children with failed hearing screenings after being referred and evaluated by ENT or Audiology, with 16 of those children necessitating some sort of intervention. While these numbers point to many children being needed to be screened in order to find one with a true pathology requiring an intervention, the impact that this earlier screening had on these 16 children cannot be taken lightly. It is a minimally invasive, low-cost screening tool with the possibility to provide life-changing interventions for children in a most critical time for development.

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